A Case Study of Seagrasses in Hawaii :

Halophila decipiens

and

Halophila hawaiiana

(Hydrocharitaceae)

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ABSTRACT

A study of the newly discovered alien seagrass, *Halophila decipiens,* has been undertaken on the island of Oahu in the Hawaiian islands. *H. decipiens* has been found in several locations throughout Oahu, from Honolulu's Runway Reef and Ala Moana Beach Park, to the Windward Kaneohe Bay, and South Shore's Kahala Bay. The main study site focuses on the lagoon fronting the Kahala Mandarin Hotel, where a population of the native Halophila hawaiiana grows adjacent to the alien *H. decipiens.* Four 100m transects were set up parallel to the shoreline in an attempt to quantify the population densities for both species' populations by counting individual leaf pairs in a 9cm X 9cm quadrat area every 5m along each 100m transect. The data showed that the alien seagrass populations are much more dense, extensive and abundant than the native seagrass, whose populations are sparse and delegated to only one small corner of the lagoon. Upon further study, the alien seagrass was found growing in several locations along the Kahala Bay shoreline, downstream from the initial study site. These populations were mapped using GPS, and no native seagrasses were found amongst them.

From the Kahala Bay study, it is clear that the alien seagrass is taking over the habitat of the native seagrass. The native seagrass was not found in any of the other survey sites where the alien *H. decipiens* was discovered. In addition, the native seagrass has a native predator, the native snail, *Smaragdia bryanae.* In laboratory experiments where the native snail has been given a choice, the native snail has been found to favor grazing the native seagrass over the alien. Biologically, due to differences in plant morphology and reproductive biology, *H. decipiens* has a greater reproductive potential than the native *H. hawaiiana.* All these factors show that the alien seagrass poses a serious threat to the native endemic *H. hawaiiana*, which has coevolved with the native snail. If the alien continues to outcompete the native seagrass, a decline or even extinction of *H. hawaiiana* is a possibility, and repercussions on the native snail and benthic habitat are a cause for speculation.

INTRODUCTION

A population of *Halophila decipiens*, a non-native seagrass, has recently been discovered growing near populations of the native Hawaiian seagrass of the same genus, *Halophila hawaiiana*, in Kahala Bay, Oahu [Fig. 1]. Both seagrasses look similar in appearance, with small, oval green leaves [Fig. 2], and can be found in the sandy reef flats close to shore. *H. decipiens* is common throughout the tropics. It inhabits the

Indian, tropical Atlantic, and western Pacific oceans (McRoy and McMillan, 1977), but has never before been spotted in Hawaiian waters, whereas the native *H. hawaiiana* is endemic to Hawaii. Before the arrival of the *H. decipiens, H. hawaiiana* was the only seagrass in existence in the Hawaiian islands.

Due to differences in plant morphology and reproductive biology, the alien species has a higher reproductive potential than the native seagrass. In addition, *H. hawaiiana* has a natural predator, the native snail, *Smaragdia bryanae*. In laboratory tests, the native snail prefers *H. hawaiiana* over the alien *H. decipiens*. This gives the alien seagrass an even greater competetive edge. Since both species were found to inhabit the same area in Kahala Bay, our main study site, competition is definitely an issue.

The purpose of this study is to research the current population of *H. decipiens* in Kahala, concentrating on qualitative visual surveys as well as collection of quantitative data on species abundance of both the native and alien seagrass. Another objective is to search for other populations of *H. decipiens* in areas where the native seagrass is known to occur in order top assess the spread of the alien seagrass throughout Oahu.

BACKGROUND

Halophila decipiens was first discovered growing in the Hawaiian Islands in October 2000 by Dr. Catherine Unabia, who found it living alongside a hearty population of *Halophila hawaiiana* (Unabia, personal communication, 2001). Both species are seagrasses in the genus *Halophila* of the family Hydrocharitaceae (Kuo, et al.,1995).

Seagrasses are angiosperms (flowering plants) that have underground rhizomes (stems), leaves, and roots. They grow in silt or sandy benthic sediments in ocean or brackish estuarine waters. They are characterized by their sturdy anchoring system and their ability to grow, reproduce and survive fully submerged in a salt water environment (Den Hartog, 1977). Pollination even occurs underwater, resulting in the germination of seedlings; however, seagrasses propagate vegetatively along their rhizome stems as well. This accounts for the rapid growth and spread of seagrass populations into undersea "meadows" (www.botany.hawaii.edu). Seagrasses are ecologically important because they stabilize the benthic sediment, provide a habitat for epiphytes, and give shelter and nursery grounds for fish and invertebrates (Den Hartog, 1977). They are also considered one of the most highly productive marine communities (Herbert, 1984).

H. decipiens differs from the native *H. Hawaiiana* species in many ways. *H. decipiens* has a wider leaf base, a hairy leaf blade, and a spiny leaf edge [Fig.2 and Fig.3] (Kuo, et al., 1995). The native seagrass has a narrower leaf base, and its leaves are smooth and hairless [Fig.4] (Herbert, 1984). The stems of the *H. decipiens* are also more flaccid than those of the native *H. Hawaiiana*, which seem more stiff and upright when compared in the field [Fig.5].

An important difference between the two plant species is their reproductive biology. *H. decipiens* is monoecious, with both the male and female flower coexisting on one plant. The female flower has 3 modified stigma, and has 20-30 seeds per ovary. The flowers and fruits develop along the nodes of the rhizome at the base of the

petioles as the plant grows; therefore, the youngest flowers are located at the growing tip of the rhizome (Kuo et al., 1995).

On the other hand, the native *H. hawaiiana* is dioecious, with separate sexes on separate plants. In the field, only female flowers have been reported, and it has not been determined how sexual reproduction occurs. The male flowers are thought to be rare, or else they may be so small that they are overlooked in the field. *H. hawaiiana* has few seeds per fruit (Herbert, 1984), a much smaller number than the *H. decipiens* species, which leads to a decreased fecundity for the native seagrass. All these factors contribute to a higher reproductive potential in the non-native *H. decipiens* when compared to the *H. hawaiiana*.

In addition, *H. hawaiiana* is consistently grazed by its natural predator, *Smaragdia bryanae* (the native snail), which is specialized to feed on native seagrass. In the field, leaves of the *H. hawaiiana*, are often found to have a distinguishing pattern reflecting the specialized grazing habit of the snail, which suggested to have coevolved with the native seagrass (Unabia, 1984).

In the lab, several experiments were performed by Dr. Unabia to compare the feeding behavior of native snails upon the native seagrass versus the alien seagrass. The experiments consisted of placing the native snail in a container with *H. decipiens* to see if it would graze the alien seagrass. If it didn't graze, the snail would be placed with native seagrass to see if anything was wrong with the snail. The experiment was performed with seagrass taken from different sites on Oahu. It was determined that the snails would not eat the alien seagrass from all sites except Ala Moana [Fig.6], and from the Ala Moana sample, if given a choice, the snail would choose to eat only the native

seagrass. This experiment clearly revealed that the native snail favored the native seagrass over the alien seagrass (Unabia, personal communication, 2001).

H. hawaiiana is considered to be an important pioneer species in the ecological habitat of nearshore benthic environments. It has the ability to grow quickly by vegetative propagation, which would allow it to gain a foothold in a disturbed area. In addition, it has the ability to respnd to perturbation by growing lateral branches when the apical bud is removed (Herbert, 1984). In actuality , all *Halophila* species are known to show similar pioneer qualities, and the concern is that *H. hawaiiana* , formerly the only pioneer seagrass species in Hawaii, may become outcompeted by the alien *H. decipiens.*

METHODS AND MATERIALS

In this study, the author and project leader Dr. Catherine Unabia performed extensive visual surveys of the entire Kahala Bay area. The goal was to search for populations of *Halophila* seagrass, both native and alien, and qualitatively compare their growth patterns, leaf shape, snail grazing damage, and population size. The survey covered a distance of a few square miles parallel to the shoreline of Kahala, but focused on two main areas: one in front of the Kahala Mandarin Hotel; and one southwest of the main stream channel (Foot Bridge) [Fig.7].

H. decipiens and *H. hawaiiana* populations were mapped using a hand held Global Positioning System (GPS) device. The GPS was stored in a sealed double plastic bag and kept above water.

The lagoon fronting the Kahala Madarin Hotel (the actual site of original *H. decipiens* discovery) was the main study area [Fig.8]. In this protected lagoon, the water was shallower and less turbid than other locations. In addition, it was the only site where any native *H. hawaiiana* grew. This enabled a closer inspection of the interaction between populations of different seagrass species.

Four 100m transect lines were designated at different distances from the beach. The lagoon was enclosed by breakwaters on either side, and the breakwaters were used as points of reference. The distance measured from the beach was parallel to the breakwater, and transects were laid out at 27.7 m (Transect A), 31.0 m (Transect B), 36.6 m (Transect C), and 40.0 m (Transect D) from shore [Fig. 8]. Distances from shore were selected according to natural markers on land and in the water. The breakwater ended at 57.0 m from shore.

Along each transect, quadrants measuring 9cm X 9cm were placed every 5 meters. The quadrants were transparent plastic, enabling the researcher to count individual seagrass leaf pairs. Species type and number of leaf pairs were transcribed on a waterproof slate, and a sample of leaves was collected in each area. The sample was collected for future analysis of native snail grazing damage on each leaf.

At other sites on Oahu, such as Runway Reef in Honolulu, Ala Moana Beach Park, and Kaneohe Bay, visual surveys were carried out in an effort to search for additional *H. decipiens* populations. Target areas included territories that the native seagrass was known to inhabit based on prior research by Dr. Unabia (Unabia, personal communication, 2001), and biologists from different government institutions aided in the effort.

RESULTS

In the visual snorkeling survey of Kahala Bay, all the patches of *H. hawaiiana* were found to be concentrated near the eastern end of the Kahala Mandarin Lagoon, by the East Breakwater. These populations extended about halfway to the float (a square floating dock for tourists to sit upon), where the *H. decipiens* began to appear [Fig.8]. From this point westward, following the downstream current heading southwest, only the alien seagrass was found in patches throughout the rest of the bay. Upon visual inspection, different populations of *Halophila* had distinguishable growth patterns: the H. decipiens often grew in dense clumps, and the H. halophila was more sparse and spread out. The dense clumps consisted of over 20 leaf pairs per 9cm X 9cm quadrat, and the more sparse populations had only about 10 or less leaf pairs per quadrat.

Upon mapping the seagrass populations with GPS coodinates [Table 1 and Figure 9] near the river mouth of the smaller river (farthest West), a certain growth parttern became apparent: the alien seagrass grew in several patches in approximate straight lines perpendicular to the shore. The *H. decipiens* preferred to grow in patchy, sandy areas where other fleshy seaweeds had not already overgrown the area.

The transect lines ran from 0 m, closest to the breakwater, to 100 m, closest to the float. The data from the transect lines were calculated as leaves/cm^3 by taking total numbers and dividing them by the quadrat area for each 5 m sampling site. These values were plotted against the distance along the 100 m transect for both species. Transect data for all four transects, A, B, C, and D, were plotted on individual graphs and placed one atop the other in order from seaward, at the top, to shoreward, at the

bottom [Fig.10]. This was done so the trend throughout all four transects could be seen at one glance. It is clear, form looking at graphs, that *H. hawaiiana* dominates the first third (approximately) of the transect starting at zero. Afterward, the *H. decipiens* takes over, with an exception only at the seaward transect D. This was due to a population of *Halophila* inhabiting a sandy patch closely fringing the reef. The entire transect has a sparse, patchy population of seagrasses due to a more marginal habitat where the reef meets the lagoon. In all the other transects, the alien seagrass dominates the transect line closer to 100 m in abundance and density. Throughout the bay, the water depth varied only by a couple feet, thus was not considered a factor in determining population densities of the two seagrass species.

Although leaf samples were collected every 5 m, the data are still being processed and are unavailable at the moment. Upon close visual inspection of the leaves, however, it was apparent that although the native seagrass suffered a more extensive grazing effort by the snail, the alien seagrass also showed signs of grazing on several leaves.

Another aspect of the study involved an island wide search for other populations of alien seagrass. Dr. Unabia and Dave Gulko, aquatic biologist from the Dept. of Land and Natural Resources, found the alien seagrass growing in approximately 20 feet of water near a sandy patch in Kaneohe Bay. The author and Dr. Unabia also surveyed the area flanking the pier across from Coconut Island [Fig.11] but found only the native species. Kevin Foster, biologist form the U.S. Fish and Wildlife Service, found a large patch of H. decipiens growing at over 80 meters depth at Runway Reef, near Honolulu

airport [Fig.12]. In addition, Dr. Unabia found *H. decipiens* growing in the waters off of Ala Moana Beach Park [Fig. 6] (Unabia, personal communication, 2001).

CONCLUSION

Halophila hawaiiana is an ecologically important species in the marine environment of Hawaii. It has been shown to be a pioneer species in stabilizing the benthic sediments and supporting a community of life, including the native snail, *Smaragdia bryanae*, that specializes in grazing on the native seagrass. A recently discovered seagrass alien to Hawaii, *Halophila decipiens*, is currently occupying the same habitat niche as the native *H. hawaiiana* in the Kahala Mandarin Lagoon. Transect data show a clear pattern of alien *H. decipiens* dominance of the lagoon habitat when comparing the abundance of the alien seagrass versus that of the native. The native sparsely inhabits a smaller area of the eastern lagoon whereas the alien is more abundantly populating a greater area. This makes sense because the alien seagrass grows more densely, and is biologically more adept at reproduction. In addition, it is not grazed as efficiently by the native snail, which prefers to graze the native seagrass when given a choice.

The extensive growth of *H. decipiens* is alarming. After surveying a large portion of Kahala Bay, only one small section of native seagrass was found. In addition, it is now known that Kahala Bay is not the only site of *H. decipiens* growth. It has also been found in Kaneohe Bay, on the Windward side, and at Runway Reef and at Ala Moana, near Honolulu.

There has been much speculation as to the time and source of the *H. decipiens* invasion. Although the alien has recently been discovered, the populations found were so extensive that they must have been growing for several years at the least. The alien may have been introduced from the Honolulu Harbor near the airport, since populations were found at Runway reef and Ala Moana, or it may have been introduced from Coconut Island, where there are ongoing marine botany research experiments. This would account for the populations discovered on the Windward side. In addition, it has been speculated that *H. decipiens* may have been introduced in the Kahala Mandarin Lagoon from the recently attached float or contamination from the Mandarin Hotel's outdoor aquariums. In all cases, there has been no proof to any of the theories; however, all are quite possible, yet it is difficult to determine the original cause of invasion.

It is difficult to predict the repercussions of *Halophila decipiens*' introduction to Hawaii. The native *Halophila hawaiiana* is endemic to Hawaii, and was the only seagrass in Hawaii for a long period of time, growing in isolation from other seagrasses, thus lacking the higher reproductive potential shown by *H. decipiens*. In the course of coevolution, *H. hawaiiana* has developed a specialized relationship with the native snail, and if its population abundance is reduced, it may deleteriously affect the native snail population. It is strongly suggested that further study be undertaken to better understand the dynamics of the alien/native seagrass interaction as well as the alien/native snail interaction in order to prevent possible extinction of both the snail and the native seagrass species, and in order to determine a strategy to restore a balance in the system.

Figure 1. Map of OAHU.

The following is a map of the island of Oahu, located in the Hawaiian islands. The survey site in Kahala Bay in the region demarcated below.

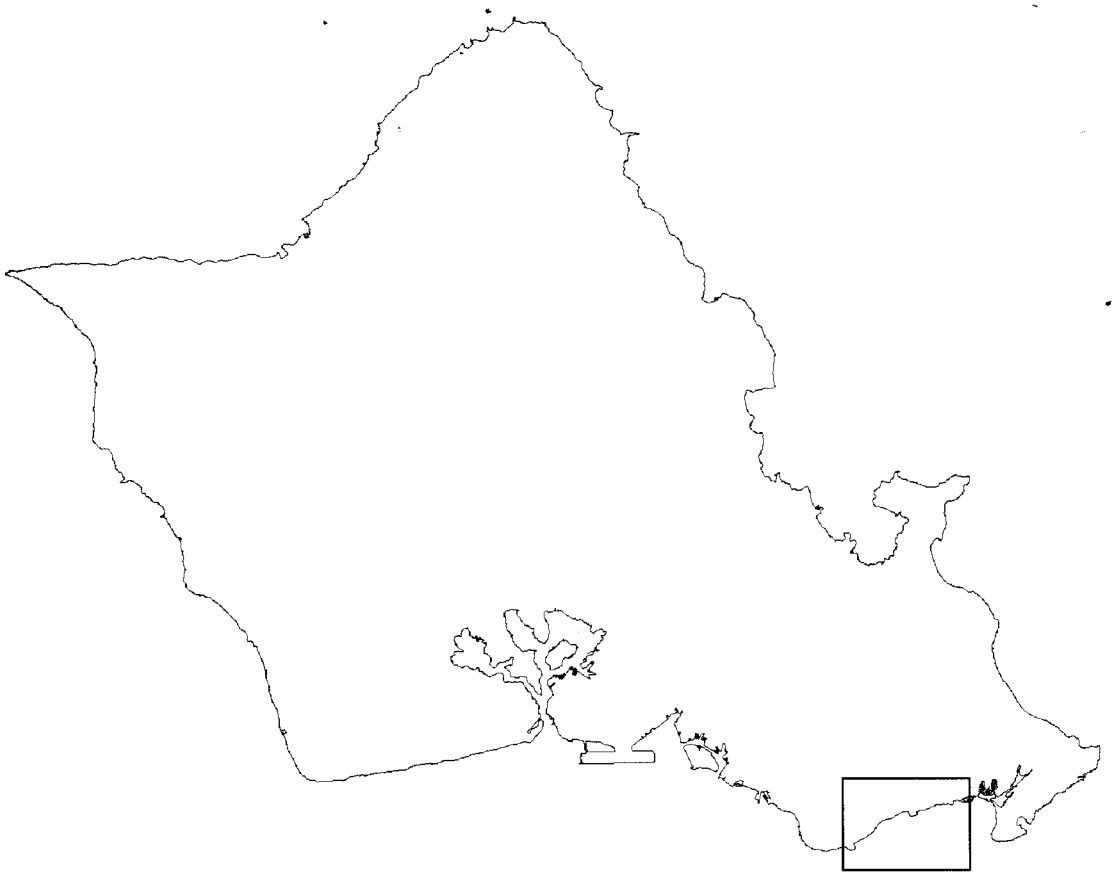
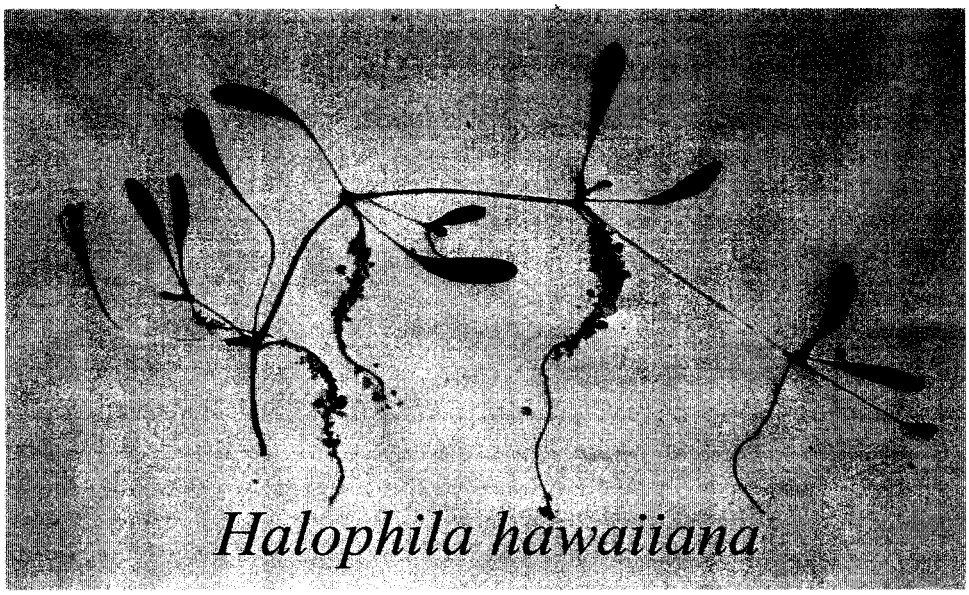


Figure 2. Comparison of *Halophila decipiens* with the native *Halophila hawaiiana*

In the pressings showing rhizomes and leaf morphology, notice the difference in leaf appearance. *Halophila decipiens* has a hairy leaf that is wider at the base. *Halophila hawaiiana* has a smooth leaf that is tapered at the base. Width of adult leaves is approximately 5 to 10 mm.



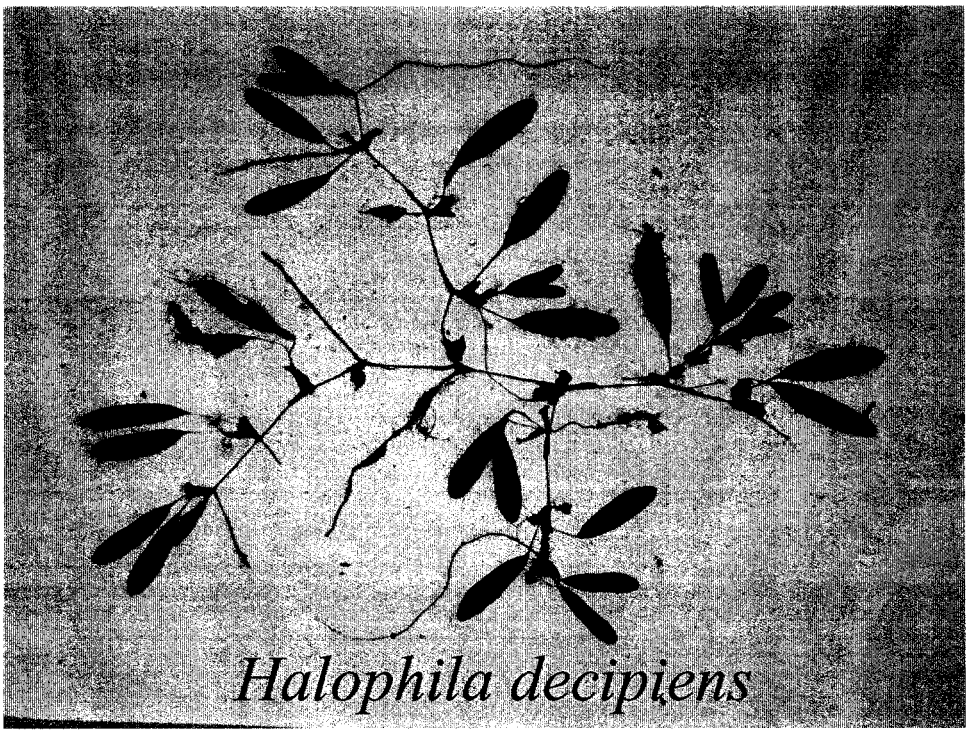
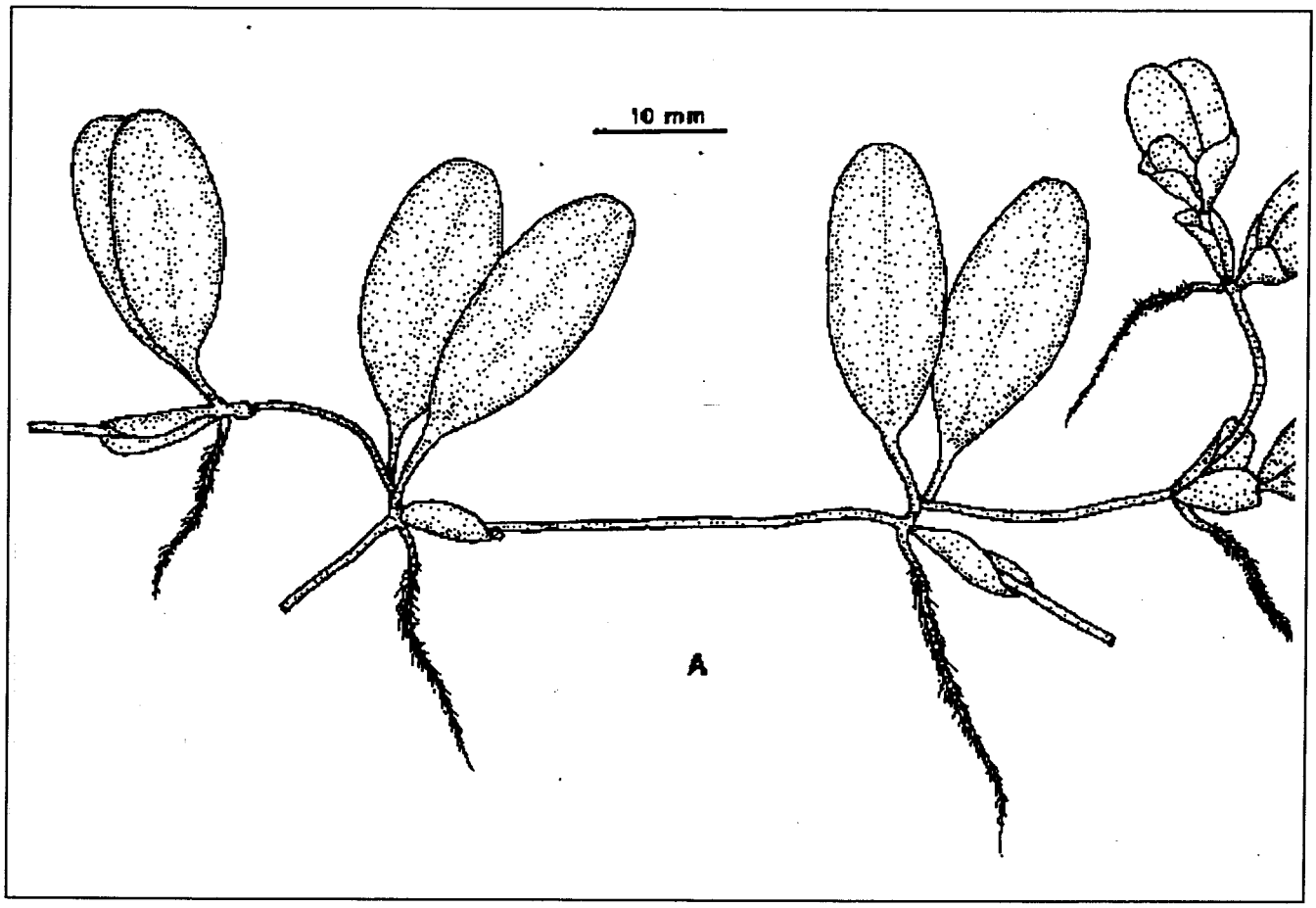


Figure 3. Several Views of *Halophila decipiens*

These figures are representative of *H. decipiens* morphology

A: rhizome and leaf anatomy (Phillips and Menez, 1988)

B: serrated leaf edge (Kuo, *et al.*, 1995)



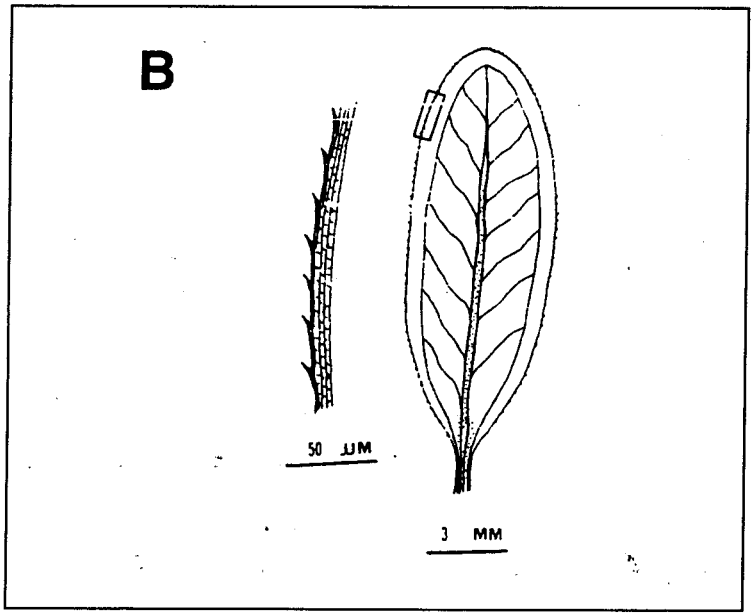
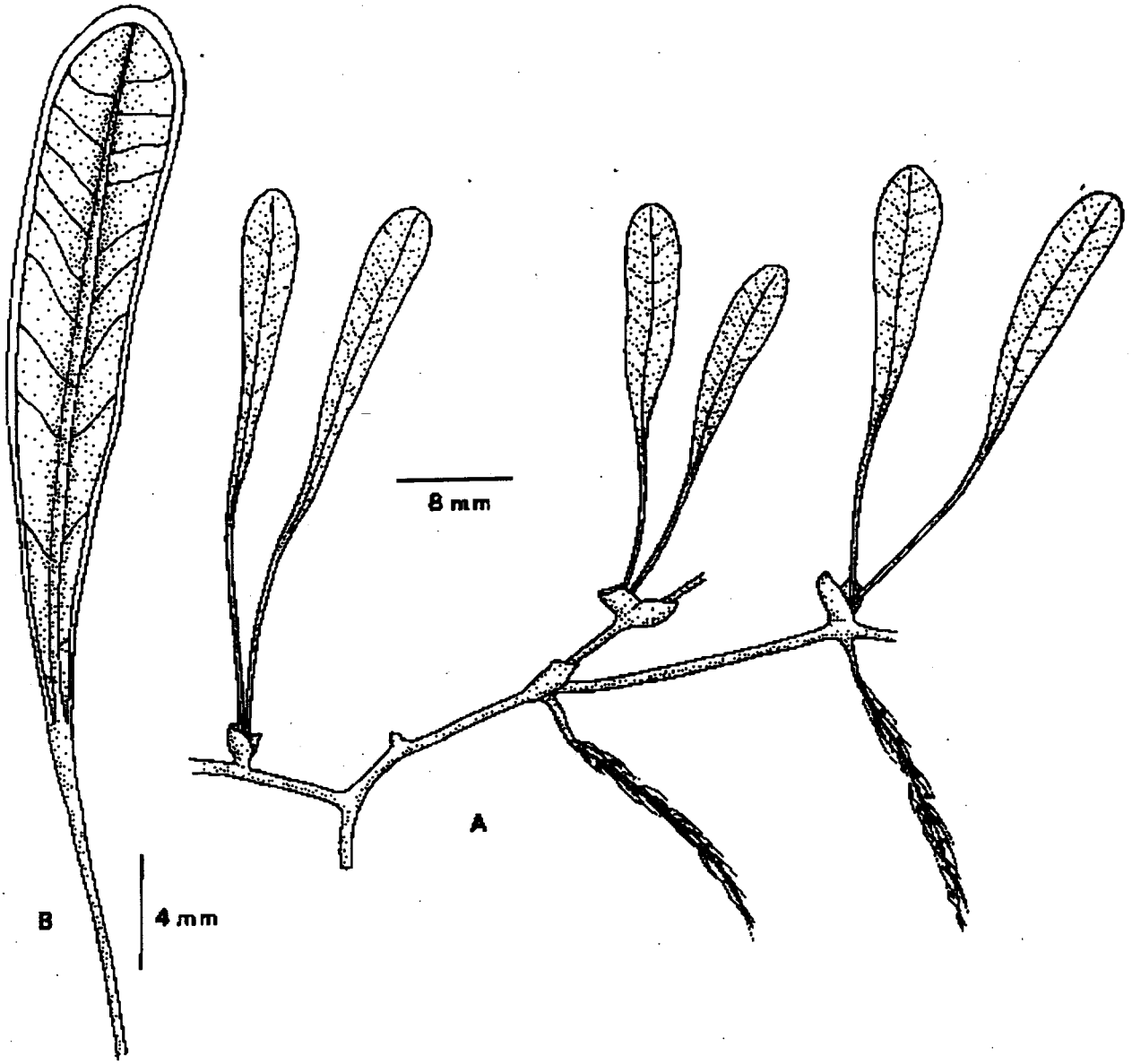


Figure 4. Halophila hawaiiana rhizome structure and leaf morphology



(Phillips and Menez, 1988)

Figure 5. Comparison of *Halophila hawaiiana* with *Halophila decipiens* in the field

a. *Halophila decipiens* (above left) has flaccid, droopy stems compared to *Halophila hawaiiana* (above right) with stiff, erect stems

b. Comparison of *Halophila hawaiiana* (lower left) and
c. *Halophila decipiens* (lower right) in the field. Notice the native has a growth pattern that is more sparse compared to the alien that grows more densely. Both photos are taken from Kahala Mandarin Hotel lagoon.

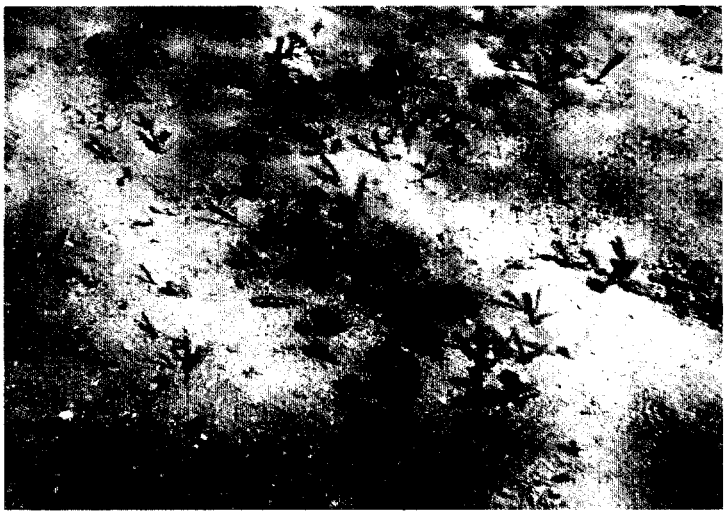
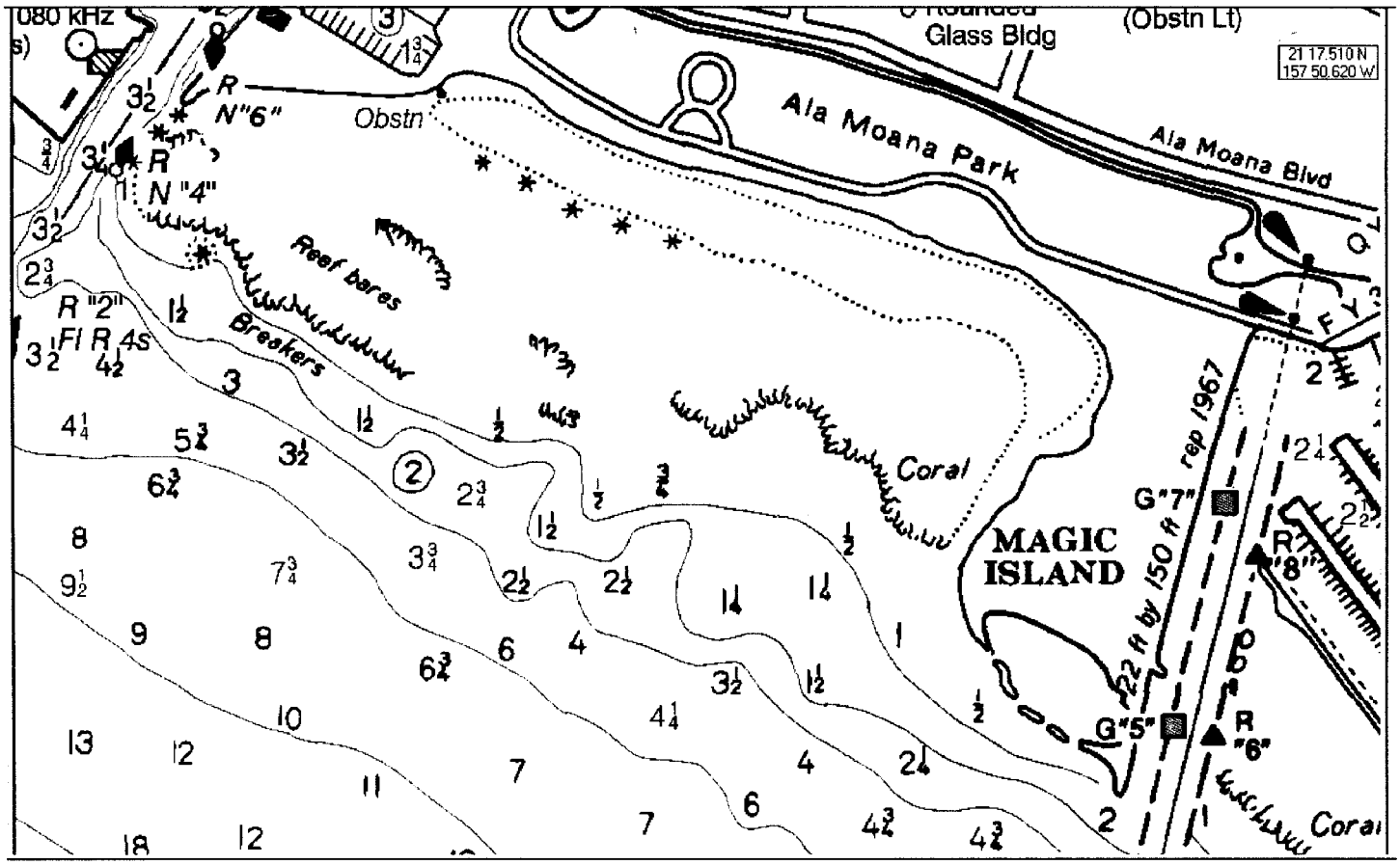


Figure 6. Ala Moana Beach Park

A qualitative survey was carried out at Ala Moana Beach Park and the presence of *Halophila decipiens* was observed; however, due to the qualitative nature of the survey, exact locations were not pinpointed.

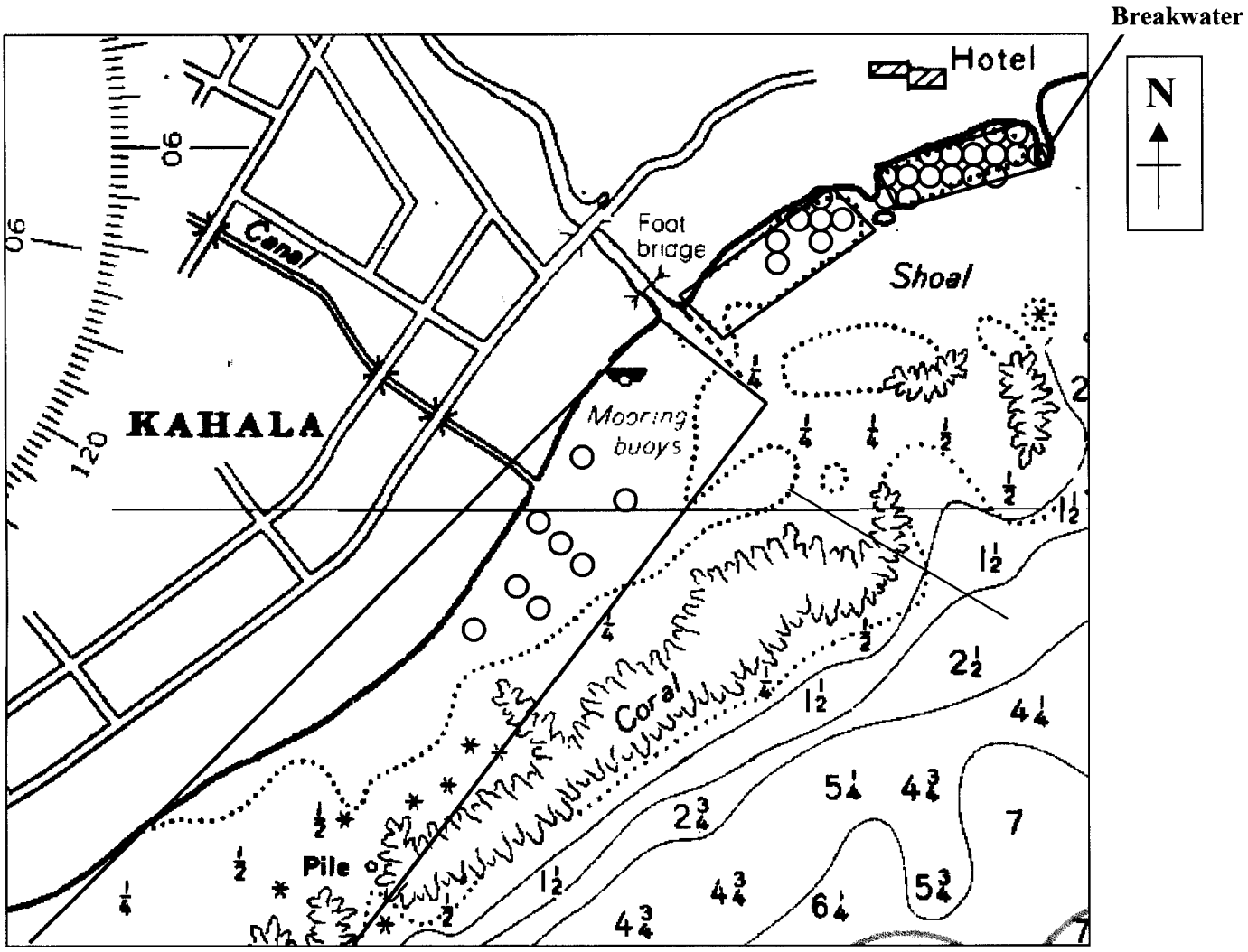


- Survey area
- Land area
- Deeper waters
- Shallow waters
- Patch reef
- *H. Hawaiiana*
- *H. decipiens*

The following map is adapted from MAPTECH Chartkit, NOAA 1997. Depths numbered on chart are in meters.

Latitude: 21 17.510 N
Longitude: 157 50.620 W

Figure 7. Kahala Survey Sites



The following map represents the Survey sites along the shoreline of Kahala Bay. *Halophila hawaiiana* was only found in the eastern corner of the Kahala Mandarin Hotel lagoon, close to the breakwater. *H. decipiens* was found all throughout the bay, all the way down the coastline.

The following map is adapted from MAPTECH Chartkit, NOAA 1997. Depths numbered on chart are in meters.

Latitude: 21 16.067 N
Longitude: 157 46.687 W

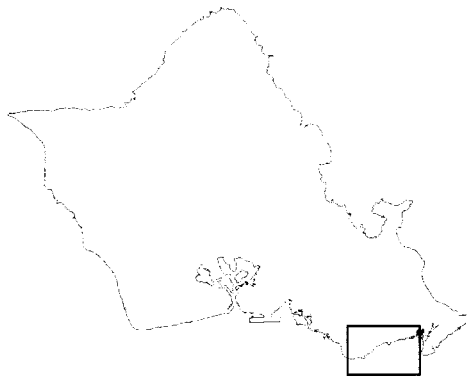
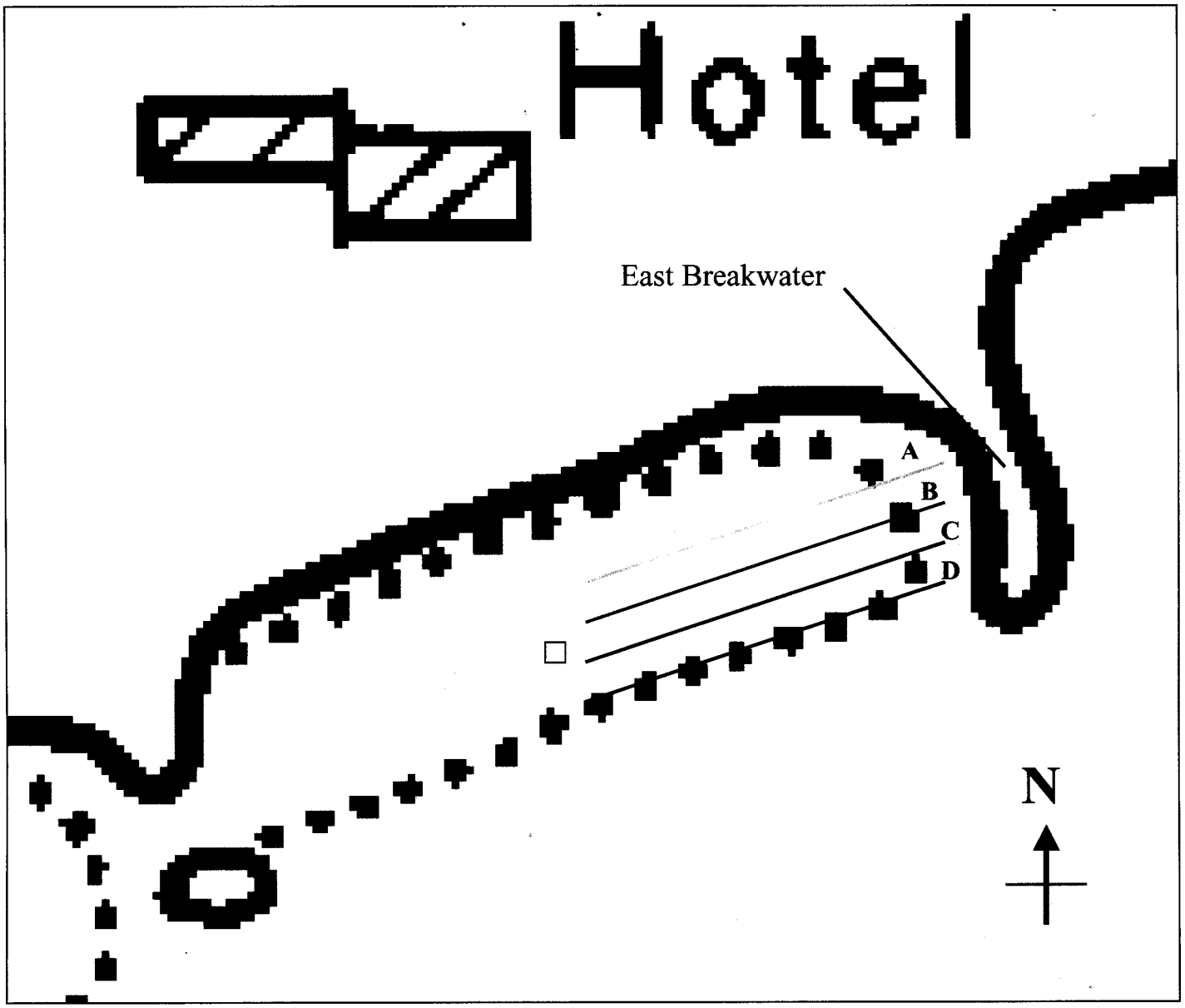


Figure. 8. Kahala Mandarin Site

□ = float
= transect A
= transect B
= transect C
= transect D

The following map shows four transect lines, labeled A B, C, and D. The transects begin at 0 meters on the eastern side of the map, closest to the East Breakwater. The transects end at 100 meters, closest to the float.



The following map is adapted from MAPTECH Chartkit, NOAA 1997.

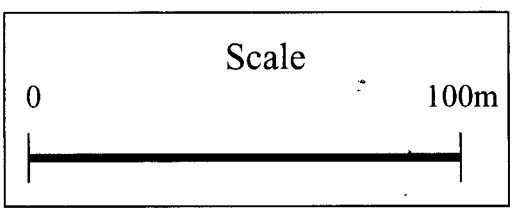
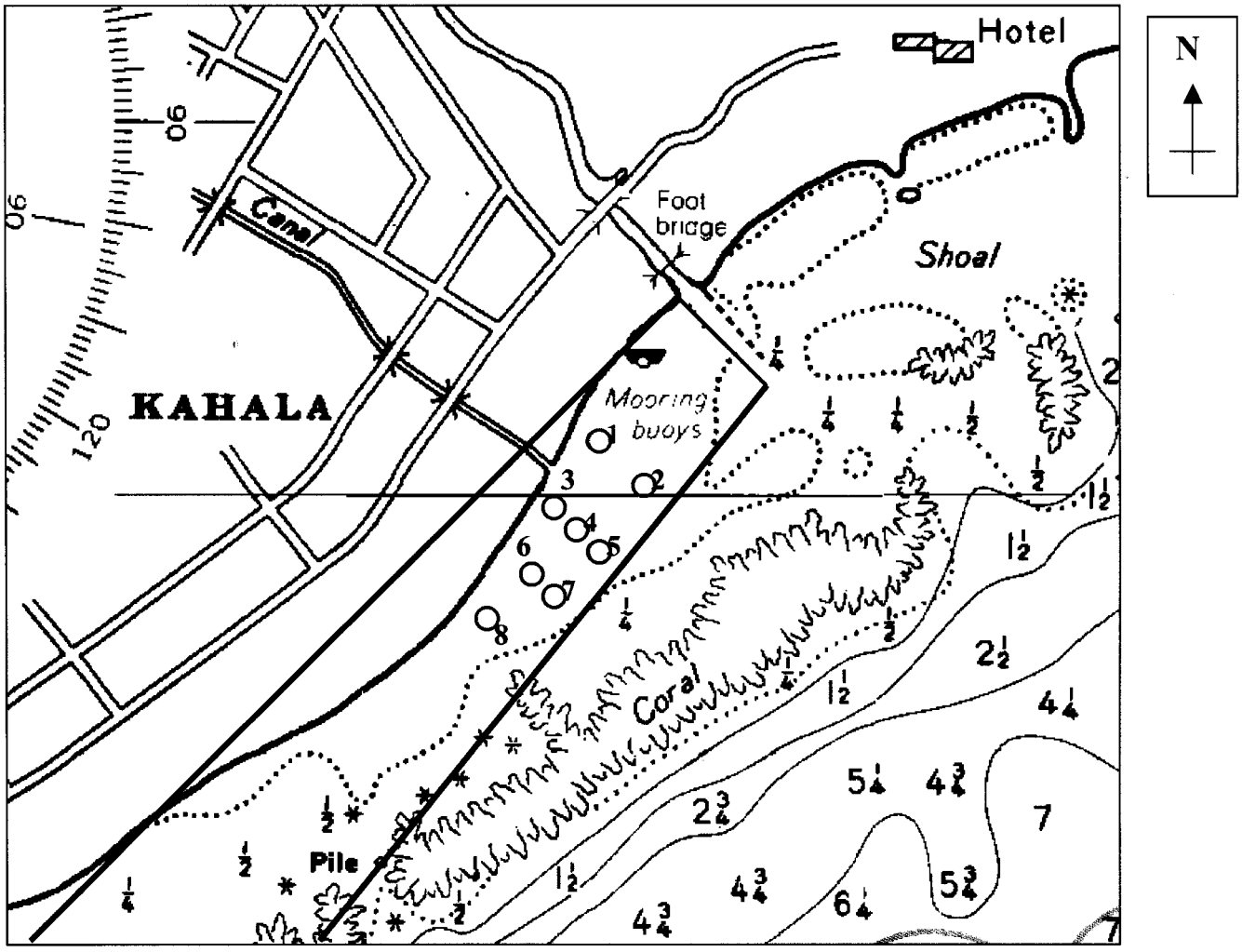


Figure 9. GPS Data Map from Kahala Bay Site



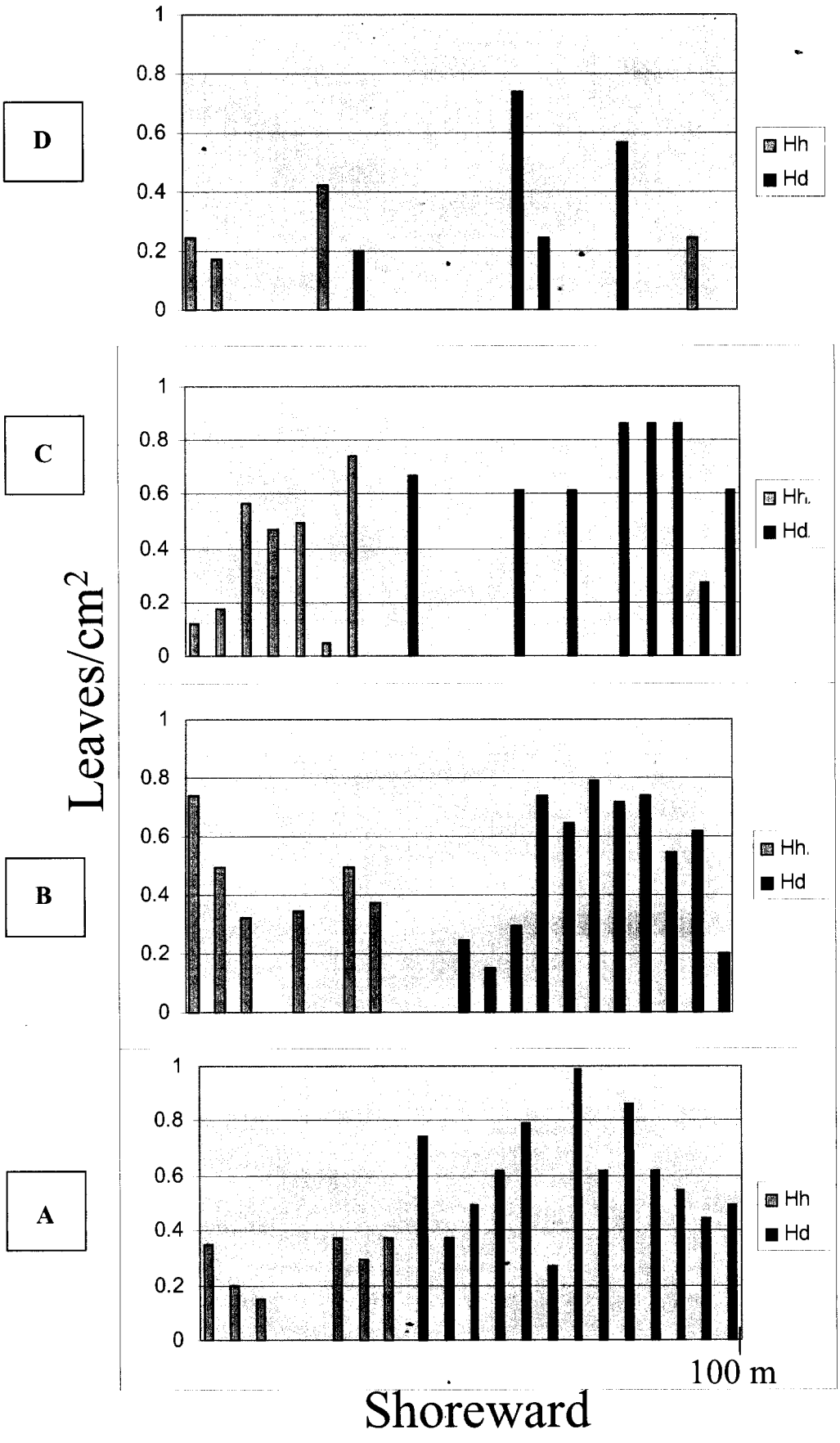
The following map is adapted from MAPTECH Chartkit, NOAA 1997.
Depths numbered on chart are in meters.

- Survey area
- Land area
- Deeper waters
- Shallow waters
- Patch reef
- *H. hawaiiana*
- *H. decipiens*

The figure above represents a visual map of *Halophila decipiens* survey sites along the shoreline of Kahala Bay. *H. decipiens* was found in patches throughout the bay, all the way down the coastline. However, this survey focused only on the western region of the bay, where significant patches of *H. decipiens* were recorded by GPS coordinates. *H. decipiens* patches are circled green and numbered 1 to 8. The corresponding GPS coordinates are offered in Table 1. See Table 1 for further details.

Latitude: 21 25.734 N
Longitude: 157 47.528 W

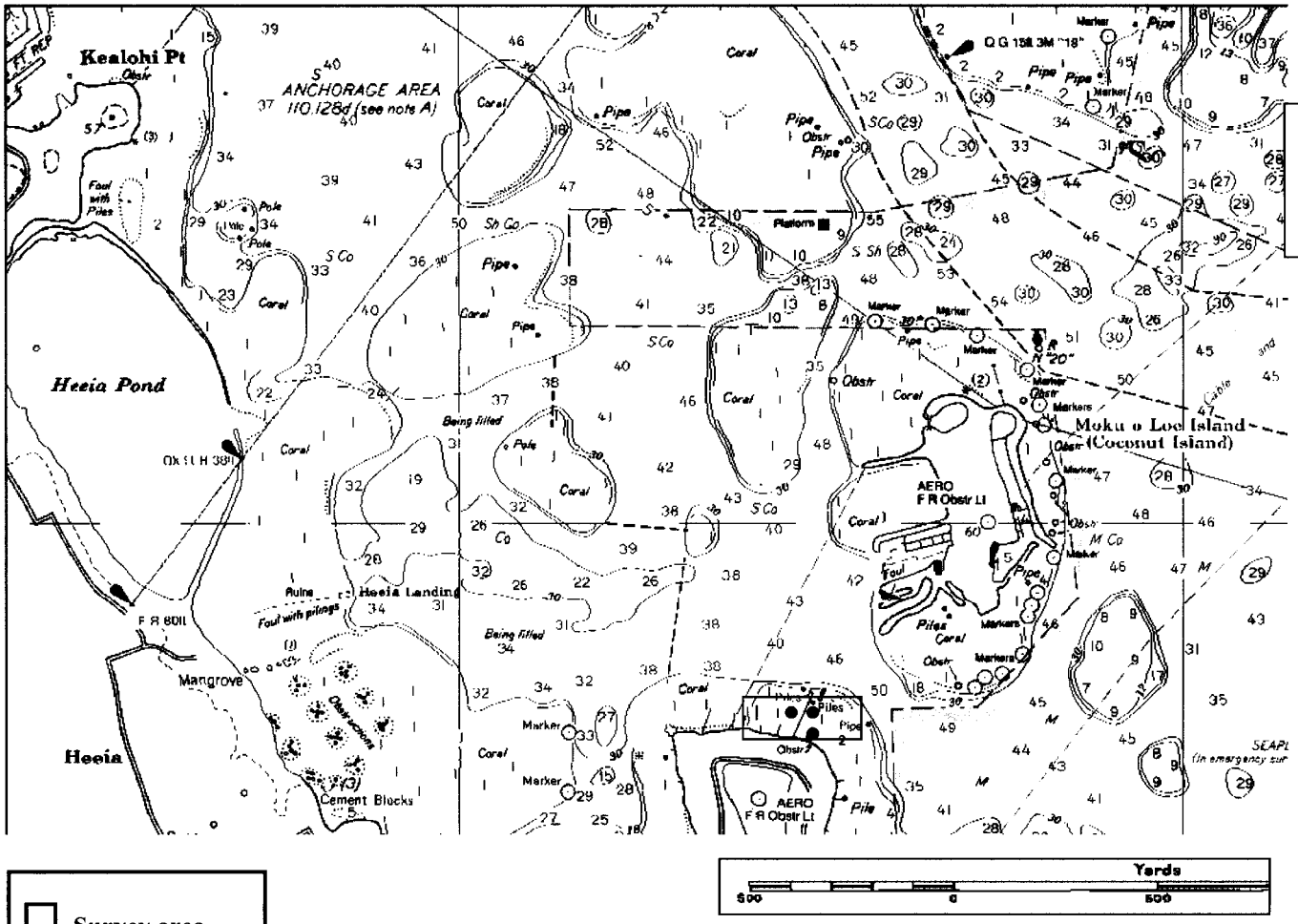
Figure 10. **4 Transects**



Abundance in 9 cm square quadrats of *Halophila hawaiiana* (Hh), and *Halophila decipiens* (Hd) in 100 m transects from the E. breakwater parallel to shore fronting the Kahala Mandarin Hotel

The lettered boxes to the left represent the transect lines, A-D

Figure 11. Kaneohe Survey Sites



- Survey area
- *H. hawaiiana*
- Land area
- Deeper waters
- Shallow waters
- Patch reef

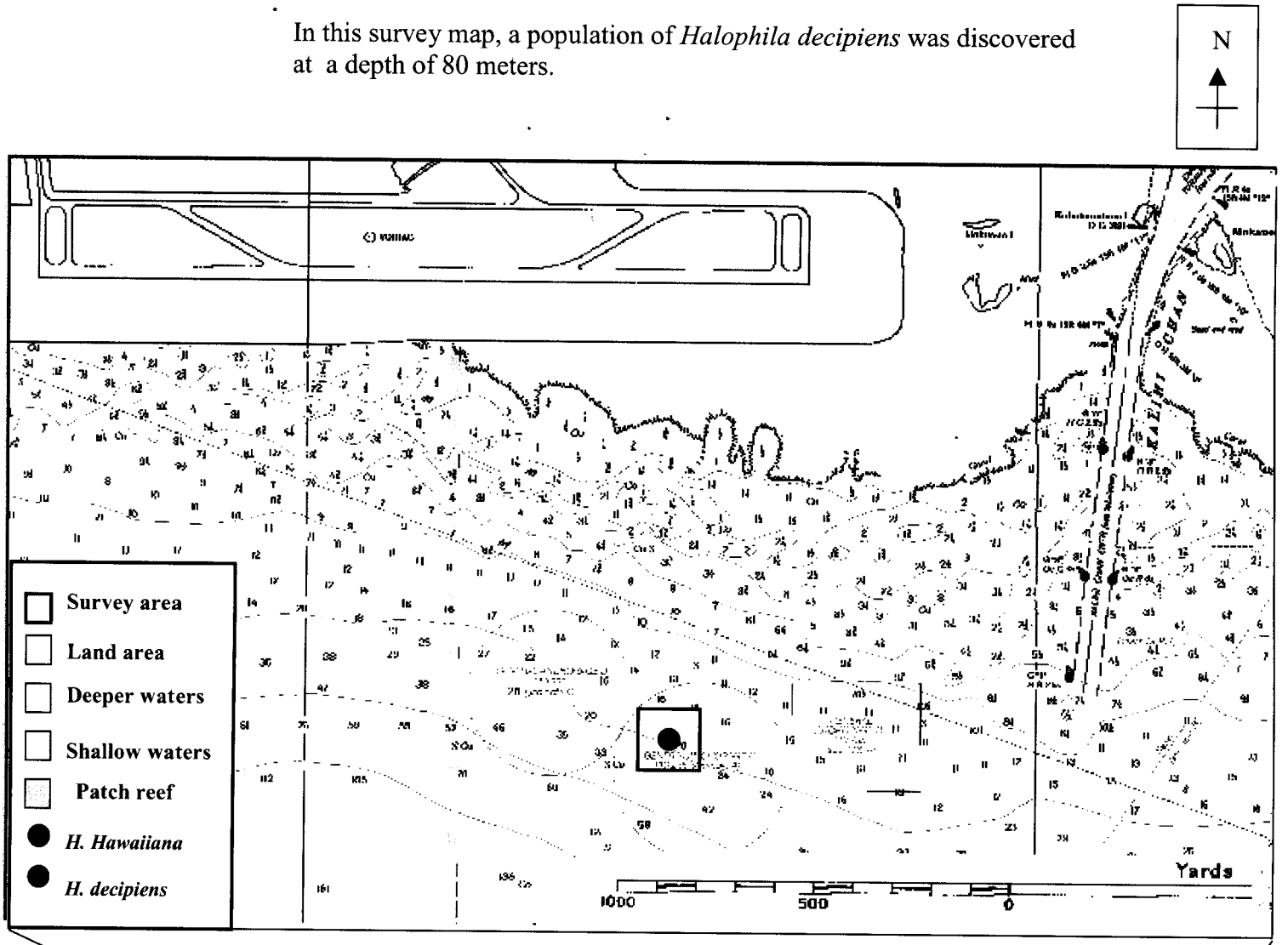
At this site, surveys were conducted on both sides of the pier across from Coconut Island. Three large, distinct patches of native *Halophila hawaiiana* were found.

The following map is adapted from MAPTECH Chartkit, NOAA 1997.
Depths numbered on chart are in meters.

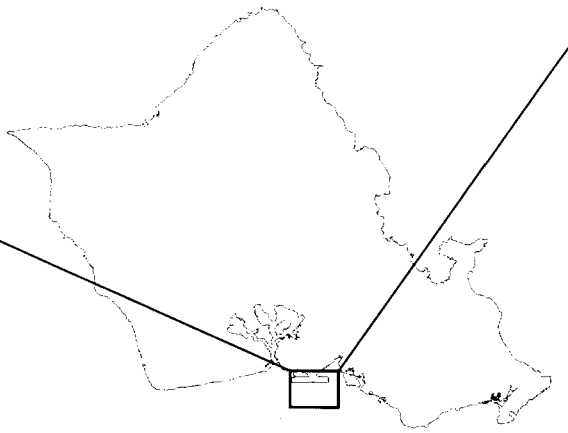
Latitude: 21 25.734 N
Longitude: 157 47.528 W

Figure 12. Runway Reef

In this survey map, a population of *Halophila decipiens* was discovered at a depth of 80 meters.



The following map is adapted from MAPTECH Chartkit, NOAA 1997.
Depths numbered on chart are in meters.



Latitude: 21 17.228N
Longitude: 157 55.003W

Table 1. GPS Data from Kahala Bay Site

The following table shows raw GPS data from the Kahala Bay survey site, west of the Kahala Mandarin Hotel. Patches where *H. decipiens* populations were found are numbered as Sites #1-8 (see map in Fig. X). Locations are recorded as visual landmarks, and the latitude and longitude are recorded from GPS data. The Description column refers to the *Halophila decipiens* population mapped in Figure X, and notes any general distinguishing observations made on the seagrass patch size/characteristics.

Site #	Location	Latitude	Longitude	Description
1	Right of stream	21'16.189 N	157'46.824 W	-
2	Right of stream	21'16.207 N	157'46.806 W	-
3	Left of stream	21'16.184 N	157'46.813 W	-
4	Left of stream	21'16.174 N	157'46.805 W	Big patch
5	Left of stream	21'16.155 N	157'46.791W	Continuous patch ends
6	German house	21'16.146 N	157'46.835 W	2 big patches
7	German house	21'16.075 N	157'46.907 W	-
8	House under construction	21'16.076 N	157'46.947 W	Couple small patches

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